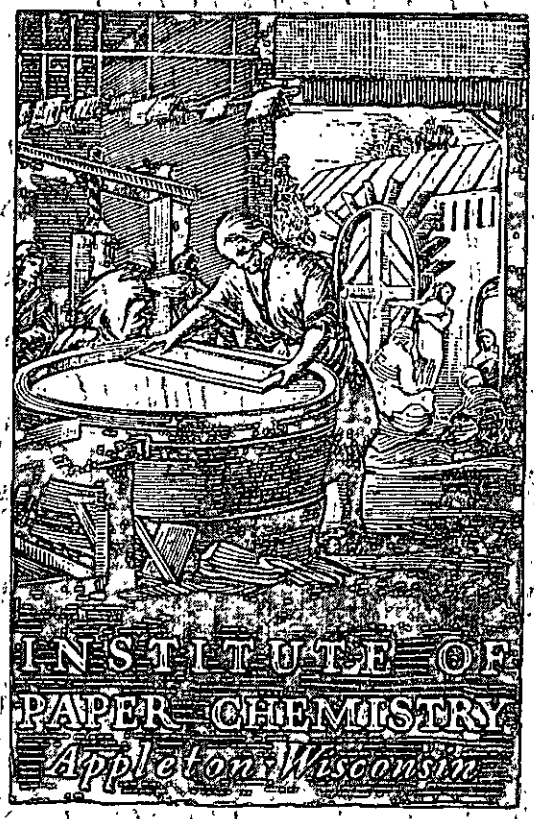

RELATIONSHIP BETWEEN CONDITIONED AND UNCONDITIONED CONCORA RESULTS AND THEIR RELATIONSHIP WITH SINGLE-FACE FLAT CRUSH

Project 1108-11

Progress Report Three

to

TECHNICAL COMMITTEE,
FOURDRINIER KRAFT BOARD INSTITUTE, INC.

April 11, 1960

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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SUMMARY

In an attempt to resolve differences in opinion regarding the appropriate procedure to follow for testing Concora flat crush, The Institute of Paper Chemistry was requested to perform the Concora test on both conditioned and unconditioned specimens for all the corrugating mediums submitted under Project 1108-17--Continuous Evaluation of Corrugating Medium--during the period June 1 through December 31, 1959. (Note: "Unconditioned" Concora specimens are tested immediately after fluting; conditioned Concora specimens are fluted, conditioned from 15 to 45 minutes at 50% relative humidity and 73°F., and then tested.) During the above six-month period, 707 samples, constituting the production of 17 different machines, were received and the results were statistically analyzed for the purpose of determining (1) the relationship between single-face flat crush and Concora flat crush on conditioned and unconditioned specimens; and (2) the relationship between the conditioned and unconditioned Concora flat-crush results.

These relationships have been determined basically in two ways, namely, (1) for all the data pooled to form a composite and (2) on the basis of individual machine results. The following is a summary of the degree of relationship as determined by correlation coefficients:

Relationship	Correlation Coefficients Composite	Range on Individual Machines
Single-face vs. Concora conditioned	0.81	0.89 to 0.45
Single-face vs. Concora unconditioned	0.78	0.84 to 0.27
Concora conditioned vs. Concora unconditioned	0.81	0.87 to 0.46

The correlation coefficients for the individual machines for all the relationships above were analyzed in order to determine if statistically a "real" relationship existed between these variables and in every case the indication was affirmative. In one or two cases, because of the limited number of samples submitted, the result may be considered on the borderline or somewhat questionable.

As a means to visualize and compare the relationship between single-face flat crush and Concora conditioned and unconditioned flat crush, the data obtained from the individual machines were plotted on graphs. The regression equations were computed for each machine and from the equations the regression lines were obtained and plotted on the graphs for each relationship. On the graphs also is shown the composite regression line as computed from the combined array of data and its position relative to the basic data of each machine. From these graphs it is evident that there exists more variability in the data of the individual machine for the relationship of single-face flat crush with Concora unconditioned than with Concora conditioned flat crush.

Because of the wide variability in regression lines and coefficients of the regression equations, the relationship between single-face flat crush and Concora flat crush may not be the same for all machines. An

investigation of this condition involved a statistical comparison of the slopes of the regression lines of individual machines with the slope of the composite regression line. For the relationship of single-face flat crush with Concora conditioned flat crush, it was found that the slopes of the regression lines for three machines--namely, C, O, and P--were significantly different than the composite slope for the combined array of data.

A similar comparison for the relationship of single-face with Concora unconditioned flat crush resulted in four machines (C, L, M, and O) having regression lines which were significantly different than the composite slope. It would appear unwise for those mills which exhibit significantly different relationships from that based on the composite to use the composite relationships as representing the relationship between combined board flat crush and Concora flat crush for their particular product.

To illustrate the use that may be given the regression equation, the Concora test results from two machines, namely, H and L, were substituted in their respective equations to obtain estimates of single-face flat crush. (Note: Relatively high correlation coefficients were found for Machine H and relatively low coefficients for Machine L.) The estimated single-face values were compared with the observed results to give an indication of the precision with which single-face flat crush may be predicted. A percentage of the computed values falling within ± 10% of the observed results are shown below:

Machine	Concora Test Conditions	No. of Samples	Distribution, %				
			± 2%	±4%	±6%	±8%	±10%
H	Conditioned	41	26.8	53.7	73.2	95.1	97.6
H	Unconditioned	41	22.0	56.1	75.6	87.8	87.8
L	Conditioned	42	35.7	66.7	81.0	88.1	97.6
L	Unconditioned	42	21.4	47.6	81.0	88.1	92.9

Thus, slightly better estimates of single-face flat crush were obtained using the conditioned Concora results.

INTRODUCTION

The Concora Medium Tester was developed, according to the inventors (1), to fulfill four requirements or needs. These are:

1. The relationship between the test on the medium and the flat crush of the combined board should be of a high precision.

2. The test should be sensitive to changes in the properties of the medium which govern its flat-crush behavior as combined board.

3. The test should be fast and be able to produce meaningful test values regardless of the atmospheric conditions prevailing at the time of the test.

4. The test should exhibit acceptable precision.

The Concora tester has filled a very useful need as a production quality-control instrument. It has been found, however, that the agreement or reproducibility within and between Concora testers may vary beyond desired limits (2,3). A recent study (4) of a new design of the Concora has indicated that those mechanical features which were responsible for the poor reproducibility appears to have been eliminated or greatly minimized.

It is highly desirable in any quality-control program associated with the production of corrugating medium that the evaluation be made as soon after sampling as technically permissible in order that corrective measures may be instituted in the process, if necessary. The manufacturer of the Concora has recommended (5) that the compression test on the fluted specimen be made immediately after fluting, because this not only reduces the time lapse between sampling and testing but also better reproducibility and correlation are obtained under these conditions. It is well known that paper properties are very sensitive

to moisture and temperature changes. When the specimen emerges from the fluting operation, it is at an elevated temperature and minimum moisture content. It is also well known that the greater the differential between the temperature and moisture content of the paper and the ambient atmosphere, the faster the rate of change in the paper. In the case of corrugating medium it would be expected that the fluted specimen would start to decrease in temperature and increase in moisture immediately after fluting. Since the rate of change is highest immediately after fluting, there is the possibility that greater variability might be encountered if tested then in contrast to compression testing after a short conditioning period. It would be expected, of course, that the magnitude of the tests would be lower after the conditioning period because of the higher moisture content. This, in itself, would not change the reproducibility of the test or the relationship with combined board flat crush; only the constants of the mathematical expression of the relationship (the regression equation) would change.

Studies carried out at The Institute of Paper Chemistry have shown that the Concora flat crush reaches sensibly a constant value in the range of 15 to 45 minutes, conditioning at 50% relative humidity at 73°F. Because of this and the anticipation of possibly better correlation with combined flat crush, the Institute adopted the procedure of conditioning the fluted specimens for at least fifteen minutes prior to compression testing. This procedure has been followed in the corrugating medium baseline study, Project 1108-17. Limited comparative studies involving conditioned and unconditioned specimens, from the same samples fluted on the same Concora fluter, have shown that, in general, the conditioning tends to reduce the variability slightly in contrast

to no conditioning. However, the difference is so small that it does not appear to be significant, for quality-control purposes, inasmuch as any variability disadvantage is offset by the marked advantage of a reduction in time between sampling and availability of the test results. The studies referred to, however, did not provide any comprehensive information as to the predictability (relationship between combined board flat crush and Concora flat crush) of the two procedures.

During the past year or so the members of the Fourdrinier Kraft Board Institute have become increasingly interested in the possibility of establishing manufacturing specifications for corrugating medium in terms of Concora flat crush. It should be emphasized that, when specifications involve a number of different paper machines and different companies, it is necessary to have a method of evaluation which can be used by all concerned to determine compliance. In other words, under these conditions it is necessary to have what might be called a "referee test" in contrast to a quality-control test. The procedure to be followed in the latter does not necessarily need to be the same in each mill; in fact, it may vary widely. Not so with the referee or standard test. Here precision and accuracy are far more important than time.

It might be well to point out at this point that, inasmuch as the rate of moisture regain during Concora testing is dependent on the ambient atmospheric conditions, the test results on specimens compression tested immediately after fluting will depend to some extent on the atmospheric conditions at the time of test. For example, the Concora results obtained when tested in an 85% relative humidity atmosphere will be appreciably lower

than when tested in a 50% relative humidity atmosphere. Thus, even in routine quality control, it would appear advisable to carry out the compression test in a conditioned atmosphere even though it may be compression tested immediately after fluting.

In an attempt to resolve the difference in opinion, as regards the most appropriate procedure to follow for the Concora flat-crush test, The Institute of Paper Chemistry was requested to perform the Concora test on conditioned and unconditioned specimens for a period of six months on samples submitted in connection with the medium baseline study, Project 1108-17. This practice was initiated on June 1, 1959 and was terminated December 31, 1959. The comparative results based on averages have been reported to the membership in the monthly baseline reports. The results obtained on the 707 samples submitted during the six-month period have been analyzed for the purpose of determining (1) the relationship between single-face flat crush and Concora flat crush on conditioned and unconditioned specimens; and (2) the relationship between Concora flat-crush results on conditioned specimens and Concora flat-crush results on unconditioned specimens. These relationships have been determined on the basis of (1) all the data pooled to form a composite and (2) on the basis of individual machine results. In the former, the composite is made up of results obtained on medium not only for different machines but also include different types of medium, i.e., semichemical, kraft, and bogus.

MATERIALS

The test data obtained on the samples of corrugating medium submitted for the Continuous Evaluation of Corrugating Medium Program, Project 1108-17, from June through December, 1959, were used in this study. The following is a tabulation of the number of rolls of corrugating medium submitted during this period from the various machines:

Machine Code	Number of Rolls
A	54
B	53
C	56
D	56
E	20
F	20
G	22
H	41
I	57
J	48
K	46
L	42
M	44
N	30
O	51
P	49
Q	18
R	6
S	6
T	4
U	4
V	3
W	1
Total	731
Composite	707

Machines R through W were not included in this study because it was felt that the number of rolls submitted were too few to give a proper evaluation for that machine.

PROCEDURE

The specimens of single-face board from which the flat-crush results were obtained were preconditioned for not less than 24 hours at 35% relative humidity at 73°F. temperature and then conditioned for at least 48 hours at 50% R.H. and 73°F. The corrugating medium used in obtaining the Concora results were preconditioned at least 4 hours at 35% relative humidity at 73°F. and conditioned at least 12 hours at 50% R.H. at 73°F. prior to fluting.

The Concora conditioned flat-crush results were obtained in the following way: After the specimens had been formed in the Concora fluter, they were conditioned at 50% R.H. and 73°F. for not less than 15 or more than 45 minutes before being tested in a H. and D. flat-crush tester. The unconditioned Concora results were obtained from specimens that were tested immediately after being fluted.

The composite correlation coefficient which determines the overall degree of relation between single-face flat crush and Concora conditioned flat crush for the combined data was computed from the following formula:

$$r = \frac{N\Sigma X_1 Y - (\Sigma X_1)(\Sigma Y)}{\sqrt{[N\Sigma X_1^2 - (\Sigma X_1)^2][N\Sigma Y^2 - (\Sigma Y)^2]}} \qquad (1)$$

where N = the total number of sample rolls submitted from all the machines,

Y = single-face flat-crush results,

X_1 = Concora conditioned flat-crush results.

The composite correlation coefficient, showing the degree of relationship between single-face flat crush and Concora unconditioned flat crush was computed in a similar manner from Formula (1) except that X_2 (unconditioned Concora results) were used in place of X_1.

The composite regression equation, which is used to obtain the composite regression line and also to estimate single-face flat-crush values from any given Concora conditioned flat-crush result, is of the form:

$$\hat{Y} = a + bX \qquad (2)$$

where $\hat{Y}$ = the estimated single-face flat-crush value.

a = the value of $\hat{Y}$ when the Concora result is chosen as zero or also is the intercept of the regression line.

b = the average change in single face for a unit change in Concora flat crush or can be referred to as the slope of the regression line.

X = any given Concora flat-crush result.

The regression form in (2) above would also be applicable for the composite relationship of single-face flat crush versus Concora unconditioned flat crush.

The correlation coefficients determining the relationship of single-face flat crush to Concora conditioned flat crush for the individual machines were computed from Formula (1) except N now is equal to the number of sample rolls submitted from the particular machine. For this same relationship, the regression equations for the individual machines were of a form similar to (2).

The degrees of relationship between single-face and Concora unconditioned flat crush for the individual machines which were found in terms of correlation coefficients were computed from a similar formula as (1) above except for the following changes:

(1) N = the number of sample rolls submitted for the particular machine.

X_2 = the unconditioned Concora results which would be substituted in place of X_1.

The form of the regression equations for single-face flat crush versus Concora unconditioned flat crush would be the same as in (2) above for the individual machines.

For the relationship of single-face flat crush to Concora conditioned flat crush, statistical comparisons were made between the slope of the composite regression line and the slope of the regression lines for each individual machine. Such comparisons were in terms of tests of significance with the following form:

$$t = \frac{b - b_o}{s_b} \qquad (3)$$

where t = the computed value which would be compared with a tabulated "t" value based on $N-2$ degree of freedom.

b = the slope of individual machine's regression line.

b_o = the slope of the composite regression line.

s_b = the standard error associated with the individual machine's regression lines.

The standard errors associated with the slope of the individual machine's regression lines were computed from the following:

$$s_b = \sqrt{\frac{[N\Sigma Y^2 - (\Sigma Y)^2] - b^2 [N\Sigma X_1^2 - (\Sigma X_1)^2]}{(N - 2)[N\Sigma X_1^2 - (\Sigma X_1)^2]}} \qquad (4)$$

where N = the number of samples of submitted for the particular machine.

Y = single-face flat-crush results

b^2 = the square of the slope of the regression line for the particular machine.

X_1 = the Concora conditioned flat-crush results.

For the similar relationship of single-face flat crush versus Concora unconditioned flat crush, the statistical comparison in slopes would be the same as in (3) above while the standard errors associated with the individual machine's regression lines would be similarly computed from Formula (4), except X_2 (the unconditioned Concora results) would be used in place of X_1.

A composite intercorrelation coefficient, determining the degree of relationship between the conditioned and unconditioned Concora flat-crush results, was calculated from a formula similar in form to (1). The formula with similar notation used in the preceding procedures is as follows:

$$r = \frac{N\Sigma X_1 X_2 - (\Sigma X_1)(\Sigma X_2)}{\sqrt{[N\Sigma X_1^2 - (\Sigma X_1)^2][N\Sigma X_2^2 - (\Sigma X_2)^2]}} \qquad (5)$$

where N = the total number of samples submitted from all the machines

X_1 = the Concora conditioned flat-crush results.

X_2 = the Concora unconditioned flat-crush results.

The intercorrelation coefficients for the relationship of Concora conditioned versus Concora unconditioned flat crush for the individual machines were computed from (5) above except that N would equal the number of samples submitted for the particular machine.

DISCUSSION OF RESULTS

The results obtained on the 707 samples of corrugating medium submitted in connection with the Corrugating Medium Continuous Baseline Study, Project 1108-17, during the period June 1, 1959, to December 31, 1959, have been analyzed statistically to determine the relationship between (a) single-face flat crush and Concora flat crush, and (b) conditioned and unconditioned Concora results. Inasmuch as the 707 samples represented seventeen different machines as well as different types of material (bogus, kraft, and semichemical mediums), the analysis has been carried out for the data submitted in the following two ways: (1) Compositely and (2) individually for the different machines.

RELATIONSHIP BETWEEN COMBINED BOARD FLAT CRUSH AND CONCORA FLAT CRUSH

Composite Basis

The degree of relationship between single-face flat crush and Concora conditioned flat crush, as measured by a composite correlation coefficient computed from the data obtained on the 707 samples submitted was 0.81.

The relationship between single-face flat crush and Concora unconditioned flat crush has a composite correlation coefficient equal to 0.78. These composite coefficients are presented in Table I.

The composite regression equation for single-face flat crush versus Concora conditioned flat crush is $\hat{Y} = 4.962 + 0.772X$. The intercept of the composite regression line on the Y axis is 4.962. The slope of the composite regression line is 0.772 which represents the average change in

TABLE I

DEGREE OF RELATIONSHIP BETWEEN SINGLE-FACE FLAT CRUSH AND CONCORA FLAT CRUSH

Machine	No. of Samples	Correlation Coefficients: Concora Conditioned	Concora Unconditioned	Tabulated Values of Significance
A	54	0.68	0.56	0.27
B	53	0.88	0.76	0.27
C	56	0.63	0.27	0.26
D	56	0.70	0.60	0.26
E	20	0.75	0.77	0.44
F	20	0.62	0.54	0.44
G	22	0.45	0.61	0.42
H	41	0.89	0.84	0.31
I	57	0.77	0.80	0.26
J	48	0.79	0.79	0.28
K	46	0.70	0.50	0.29
L	42	0.55	0.32	0.30
M	44	0.51	0.40	0.30
N	30	0.71	0.81	0.36
O	51	0.69	0.54	0.28
P	49	0.52	0.57	0.28
Q	18	0.84	0.74	0.47
Composite	707	0.81	0.78	

Note: Tabulated values of significance are at the 5% level and are based on N-2 degrees of freedom.

single-face flat crush for a change of one unit in the Concora conditioned results.

The coefficients for the composite regression equation for the relationship of single-face versus unconditioned Concora flat crush are, namely, (1) intercept (a) equals 10.081 and (2) slope (b) is equal to 0.503. Table II contains the presentation of the composite regression coefficients.

Individual Machine Basis

The correlation coefficients for the individual machines which determine the degree of relationship between single-face flat crush and conditioned Concora flat crush are presented in Table I. These correlation coefficients range from a high of 0.89 to a low of 0.45.

The relationship between single-face flat crush and Concora unconditioned flat crush for the individual machines was measured in terms of correlations coefficients which are shown also in Table I. The range of coefficients for this relationship is 0.84 to 0.27.

A relationship between two variables is said to be "real" if the correlation coefficient is significantly greater than zero. In order to determine if this condition exists, the correlation coefficients for the individual machines must be greater than a tabulated value obtained from tables of significance for correlation coefficients. These tabulated values are shown in Table I and are based on N-2 degrees of freedom. In examining the correlation coefficients and the corresponding tabulated

TABLE II

REGRESSION COEFFICIENTS

Machine	Relationship: Single-Face versus Conditioned Concora — Intercept (a)	Slope (b)	Relationship: Single-Face versus Unconditioned Concora — Intercept (a)	Slope (b)
A	3.556	0.787	14.189	0.405
B	0.999	0.888	8.351	0.530
C	14.360	0.543	26.687	0.183
D	7.412	0.724	13.811	0.438
E	8.214	0.672	13.675	0.411
F	6.409	0.738	11.876	0.449
G	17.029	0.407	16.532	0.316
H	0.172	0.893	6.584	0.587
I	7.184	0.719	7.425	0.573
J	7.471	0.709	5.547	0.611
K	8.041	0.709	15.803	0.401
L	13.912	0.540	23.853	0.213
M	14.143	0.524	20.043	0.282
N	7.484	0.623	10.860	0.462
O	13.506	0.531	21.763	0.240
P	19.647	0.380	15.119	0.398
Q	-3.175	0.982	10.321	0.470
Composite	4.962	0.772	10.081	0.503

Note: General form of regression equation is $\underline{Y} = \underline{a} + \underline{b}\underline{X}$
where $\underline{Y}$ = single-face flat crush
$\underline{X}$ = Concora flat crush

values, it may be noted that, for each machine, there exists a "real" relationship between single-face flat crush and Concora conditioned flat crush.

For the relationship of single-face flat crush and Concora unconditioned flat crush, the tabulated values obtained from the tables of significance for correlation coefficients (at the 5% level of significance) as shown also in Table I, were compared to the correlation coefficients of the individual machines. It may be observed that, for each comparison, the corresponding tabular value for significance, thus indicating that a real relationship exists between these two variables. It may be somewhat questionable for Machine C which has a correlation coefficient of 0.27 compared to the tabulated value of significance of 0.26.

In Table II the regression coefficients for the regression equations for the relationship of single-face with conditioned Concora flat crush are shown for the individual machines. Considerable variation may be observed; for example: the intercepts (a) range from -3.175 to 19.647 and the slopes (b) have a low of 0.380 with a high of 0.982. In general, a low intercept will have a correspondingly high slope and vice versa.

The regression coefficients are represented in Table II also for the relationship of single-face with Concora unconditioned flat crush for each individual machine. The variation in the intercepts (a) range from a high of 26.687 to a low of 5.547 and for the slopes (b) 0.611 is the highest and 0.183, the lowest.

As a means to help visualize the relationship between single-face flat crush and Concora conditioned and unconditioned flat crush, graphs

were prepared for the individual machines on which were plotted the individual data obtained, the degree of relationship, the regression lines resulting from each machine's regression equation, and also the composite regression line obtained from the composite regression equation. If a visual comparison is made between the two relationships, namely, (1) single-face versus Concora conditioned flat crush, and (2) single-face versus Concora unconditioned flat crush as shown in these graphs, it is evident that, in general, there is more variability in the individual data of the second flat-crush relationship (single-face versus unconditioned Concora) than there is in the first (single-face versus conditioned Concora).

As may be noted in these graphs, Fig. 1 through 17 for Machines A through Q, respectively, and in Table II, the regression lines and regression coefficients vary widely from machine to machine. These data suggest, therefore, that the relationship between single-face flat crush and the Concora conditioned results may not be the same for all machines, i.e., that it may vary with fiber furnish, processing, etc. From one standpoint, it would be advantageous if the regression lines for the individual machines were not materially different from the regression line for the combined data. The latter regression line--being based on vastly more data obtained over a greater range--would ordinarily be considered more reliable than the individual machine regression equation for establishing inter- or intramachine rejection limits, or for other purposes, with some confidence that they were on a sound basis. If, on the other hand, the individual regression lines materially differ from the composite relationship, then it is desirable, if not necessary, that each

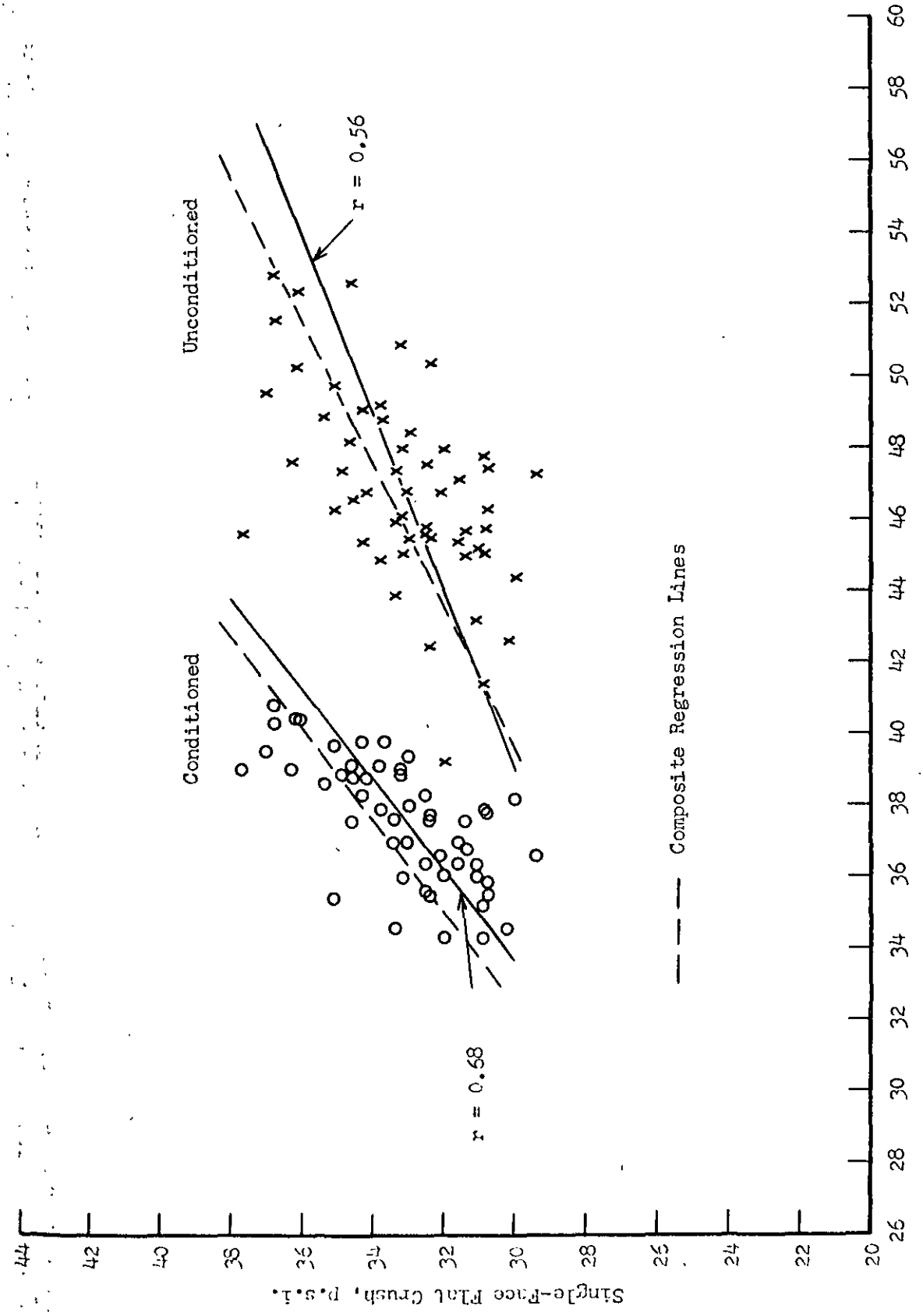

Figure 1. Single-Face Flat Crush versus Concora Flat Crush for Machine A

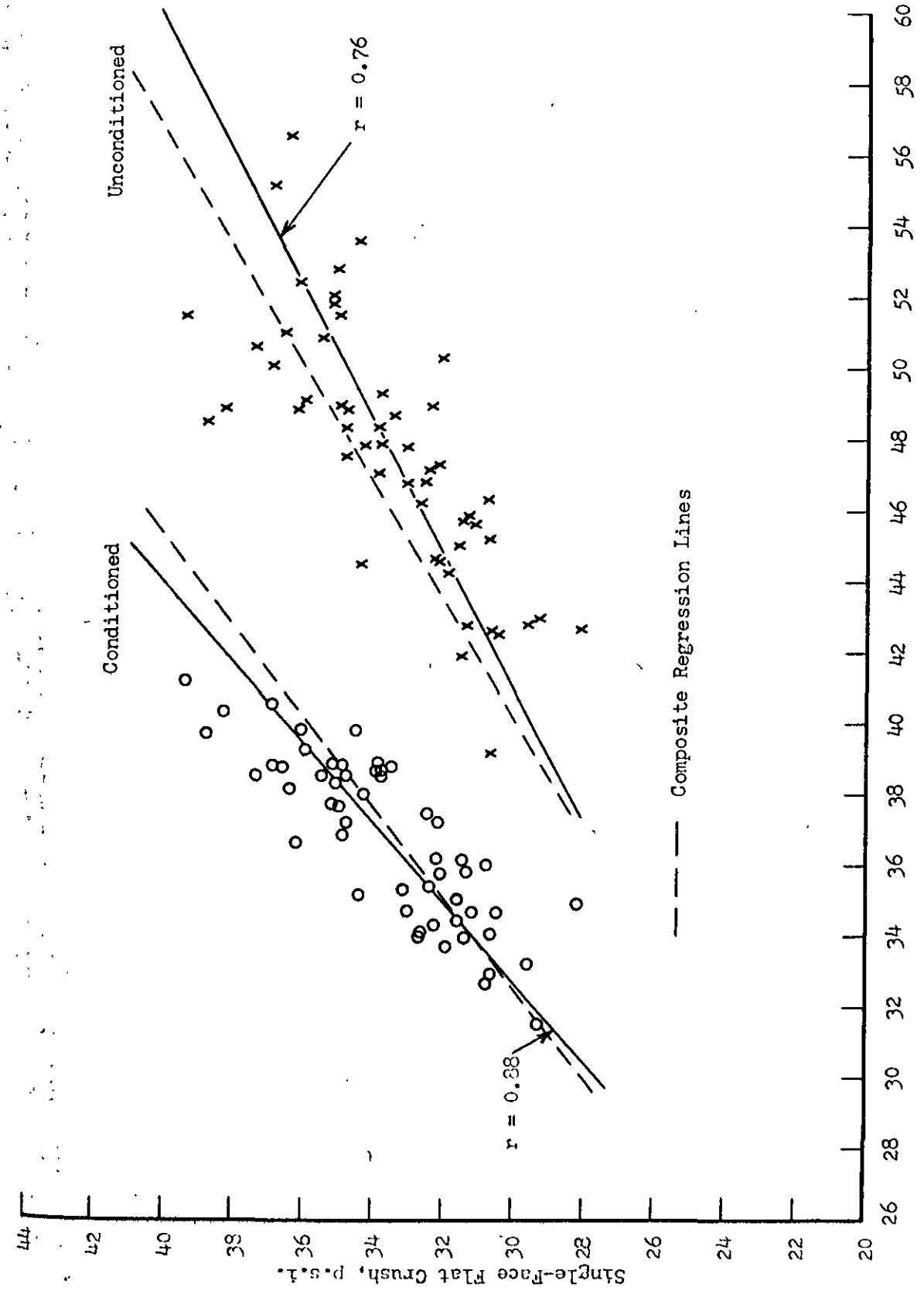

Figure 2. Single-Face Flat Crush versus Concora Flat Crush for Machine B

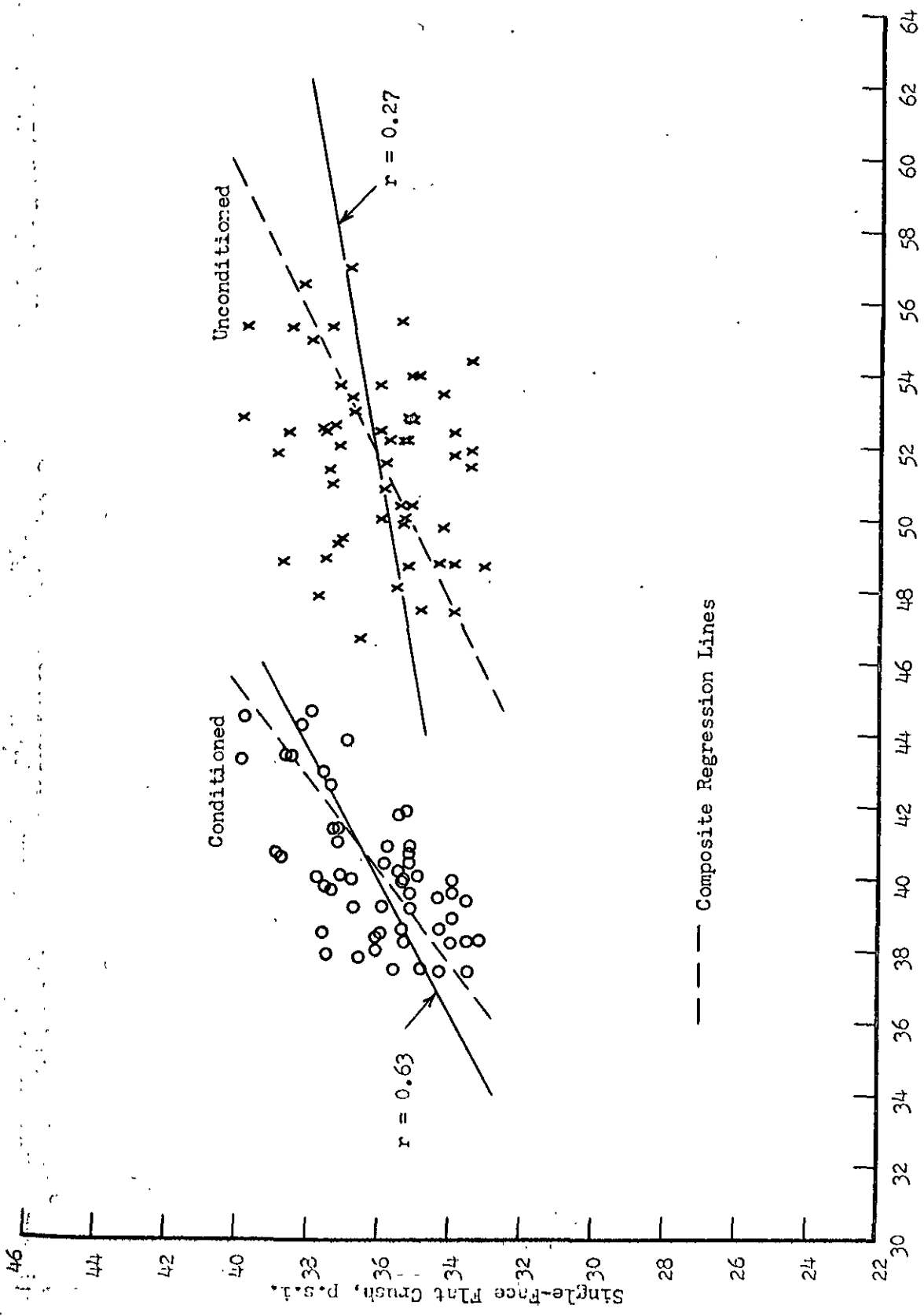

Figure 3. Single-Face Flat Crush versus Concora Flat Crush for Machine C

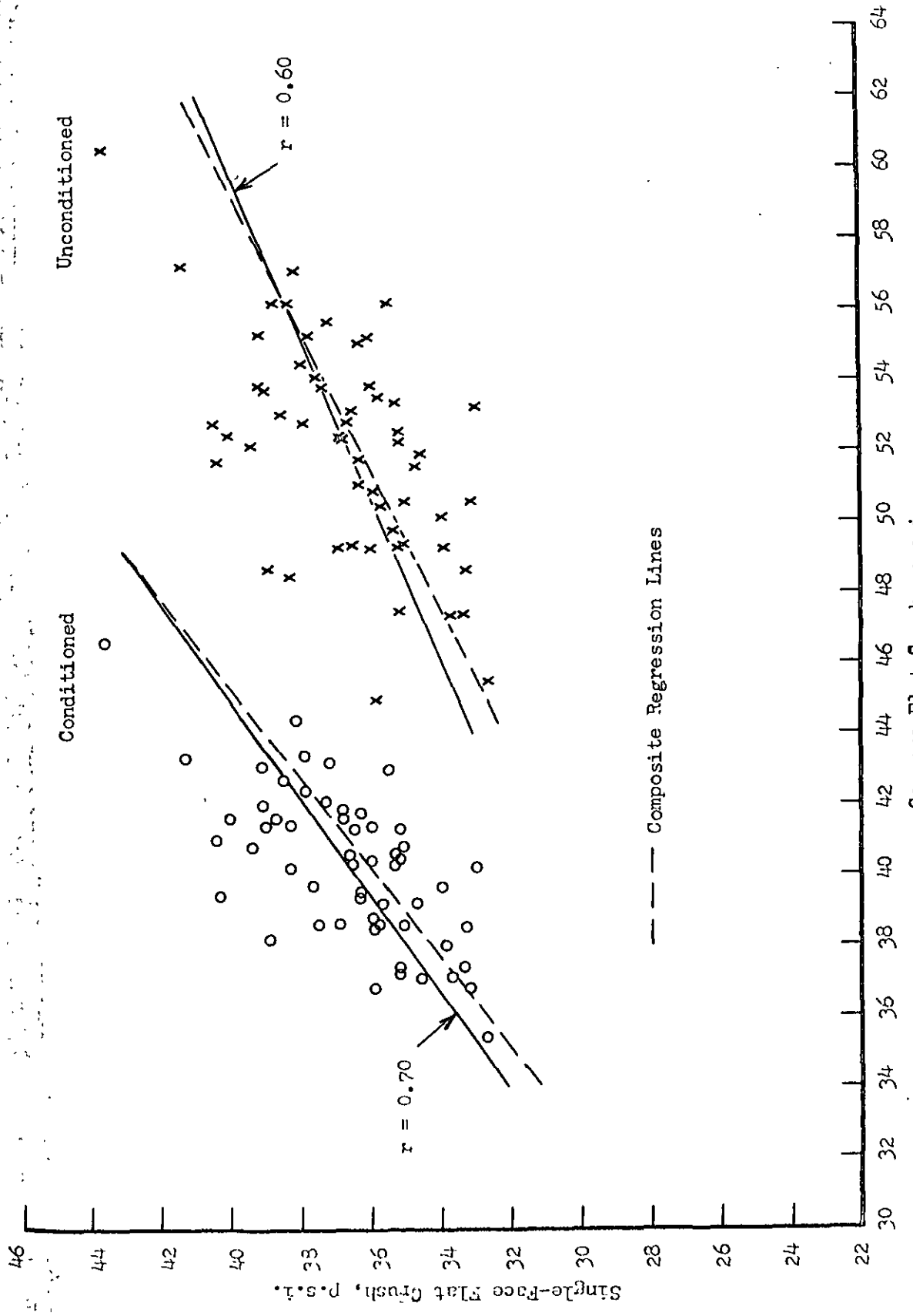

Figure 4. Single-Face Flat Crush versus Concora Flat Crush for Machine D

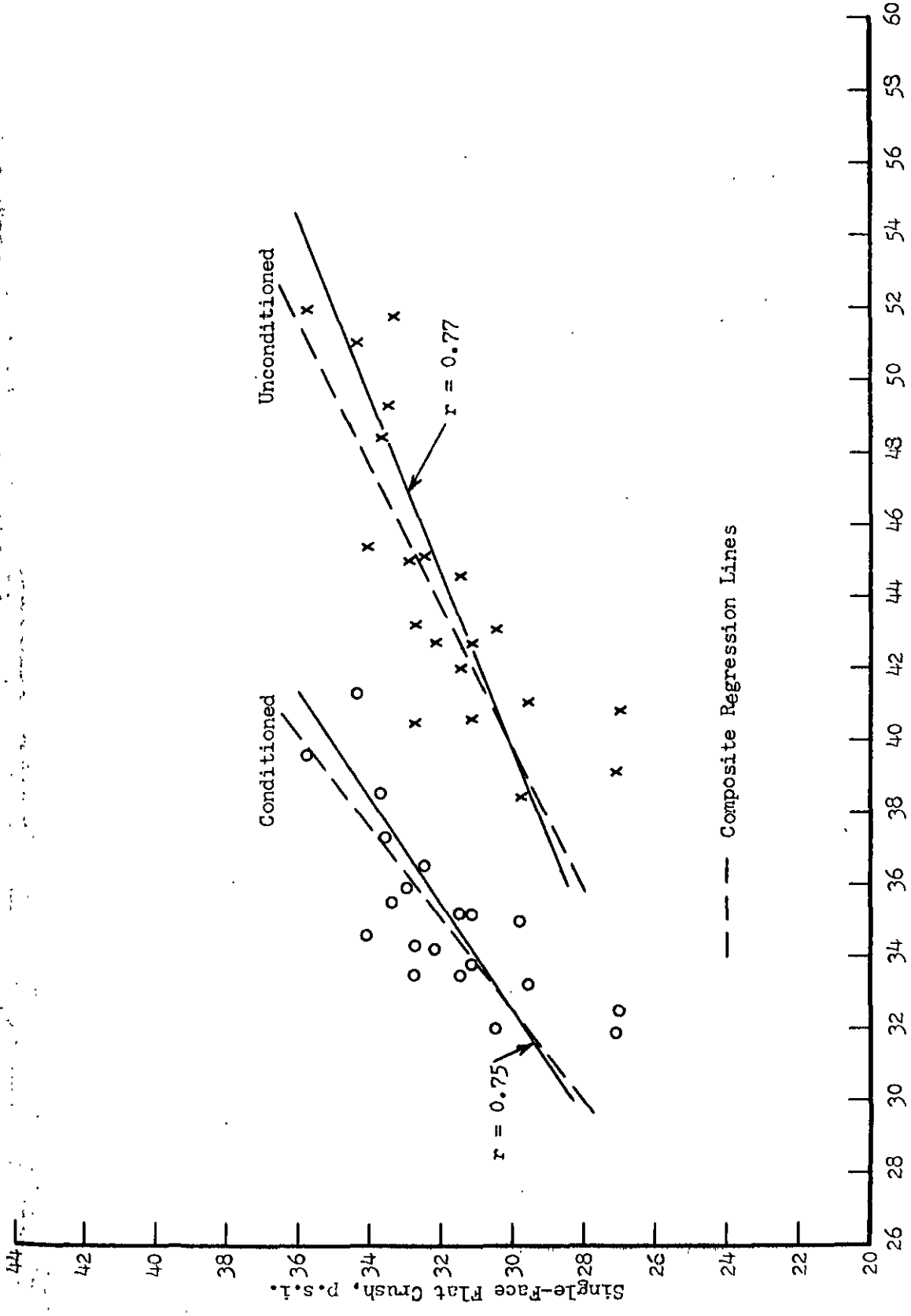

Figure 5. Single-Face Flat Crush versus Concora Flat Crush for Machine E

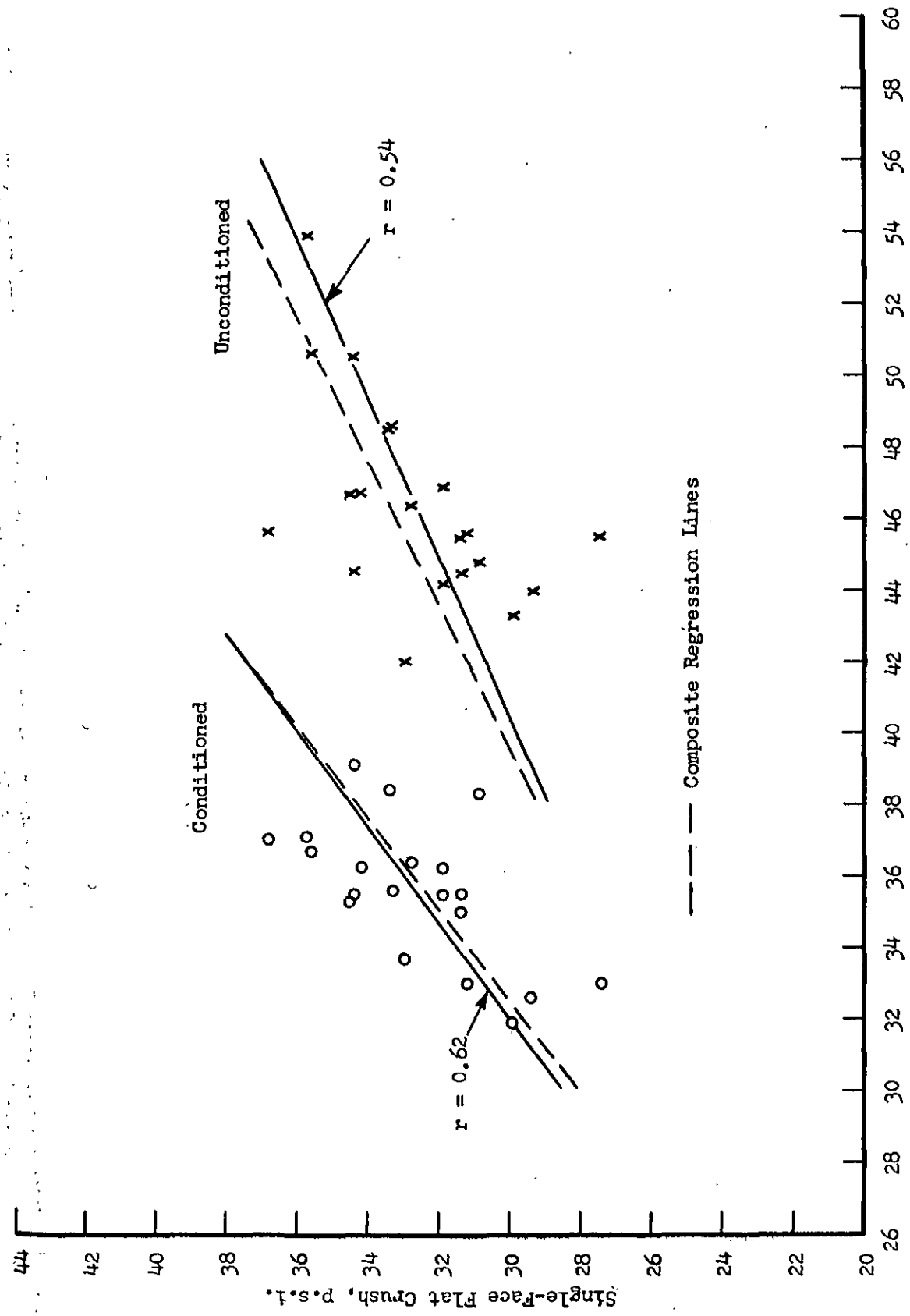

Figure 6. Single-Face Flat Crush versus Concora Flat Crush for Machine F

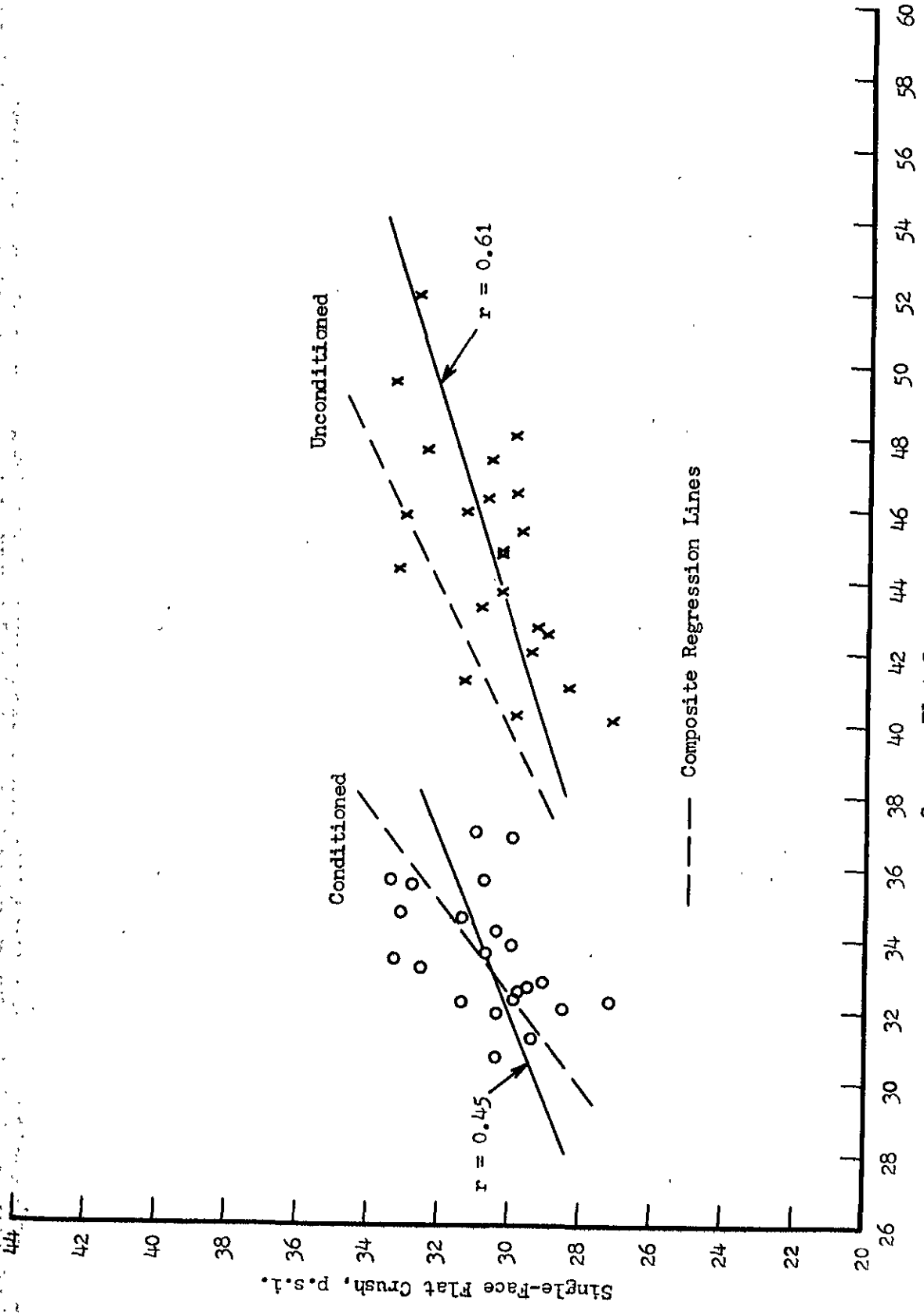

Figure 7. Single-Face Flat Crush versus Concora Flat Crush for Machine G

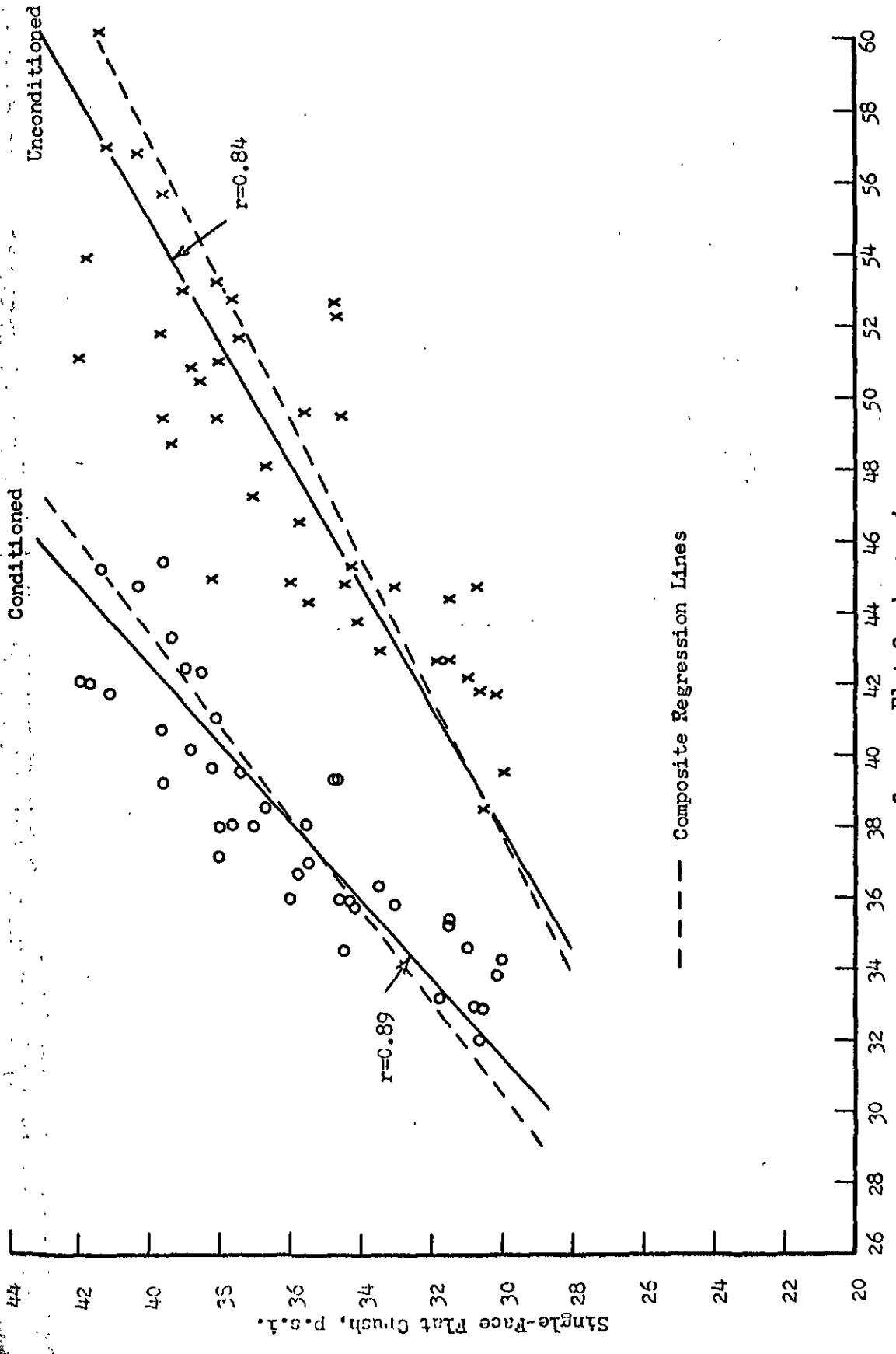

Figure 8. Single-Face Flat Crush versus Concora Flat Crush for Machine H

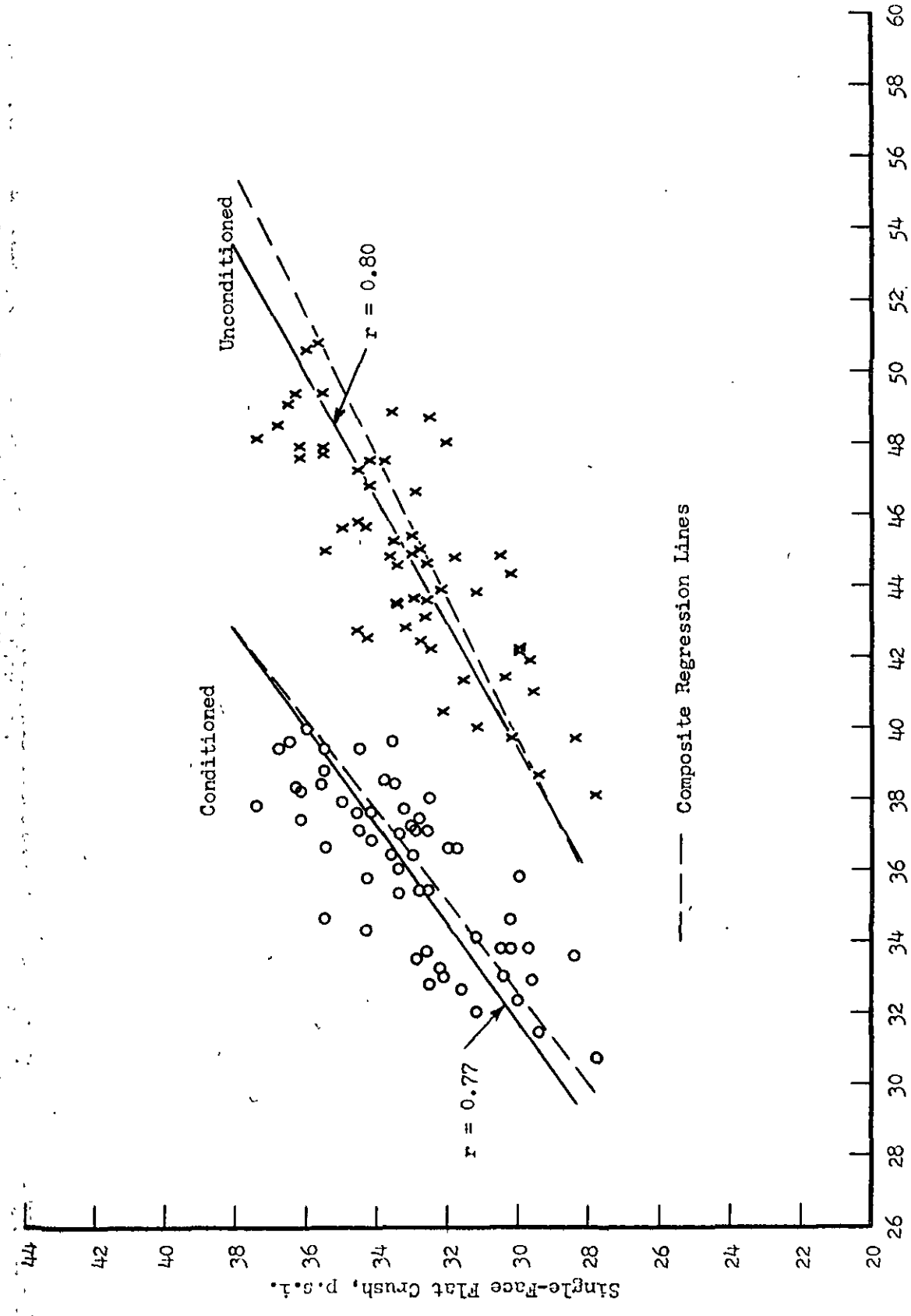

Figure 9. Single-Face Flat Crush versus Concora Flat Crush for Machine I

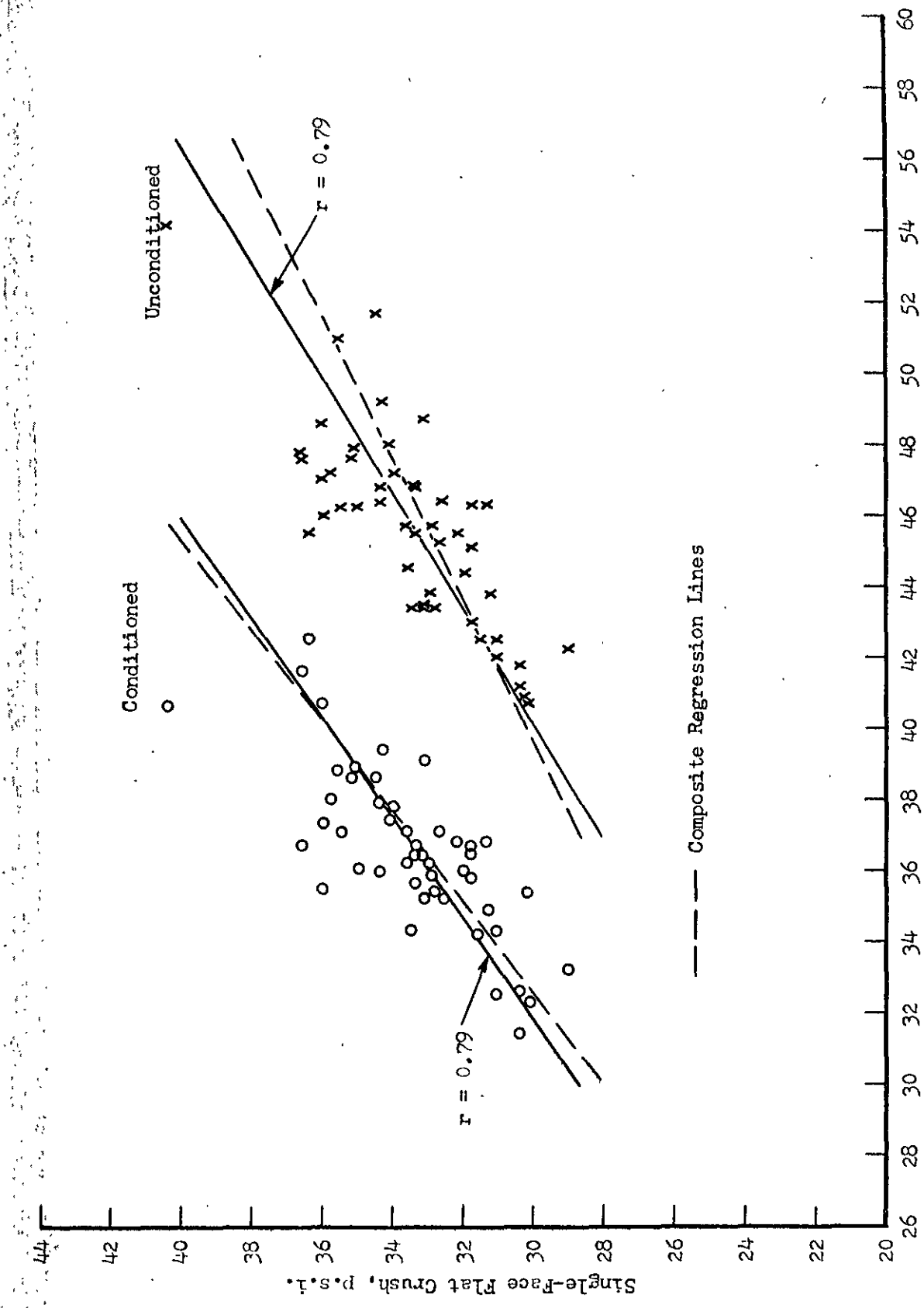

Figure 10. Single-Face Flat Crush versus Concora Flat Crush for Machine J

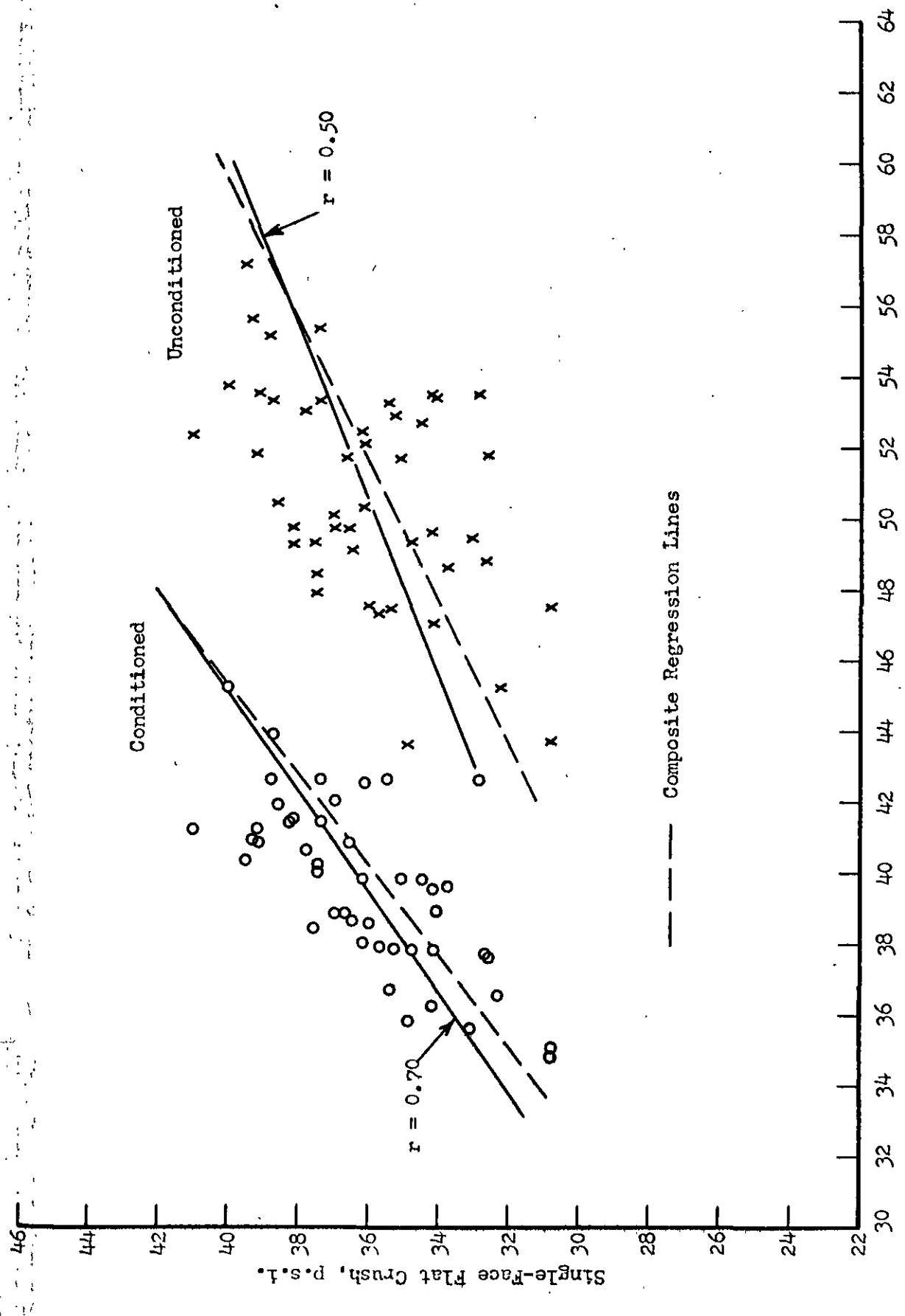

Figure 11. Single-Face Flat Crush versus Concora Flat Crush for Machine K

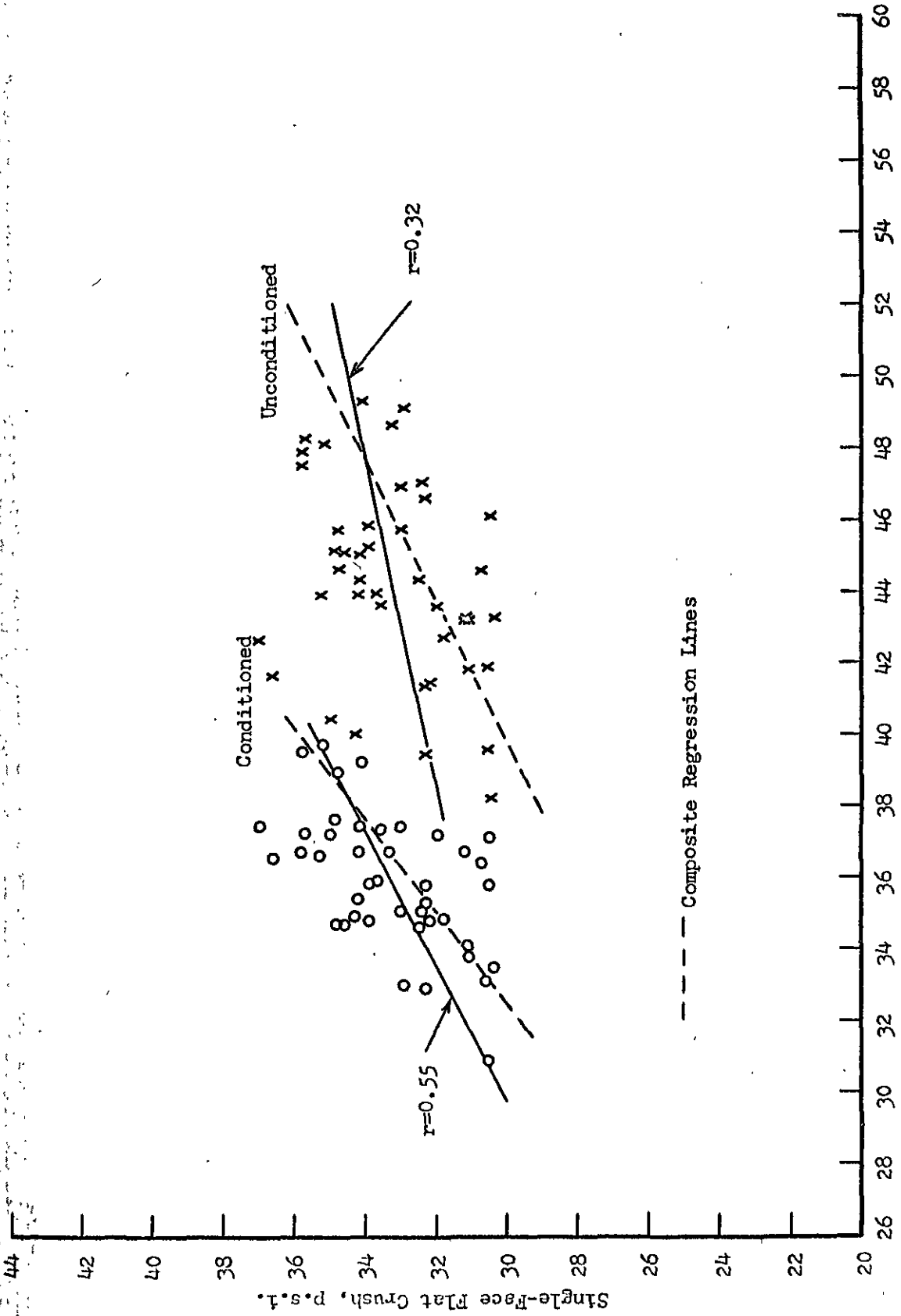

Figure 12. Single-Face Flat Crush versus Concora Flat Crush for Machine L

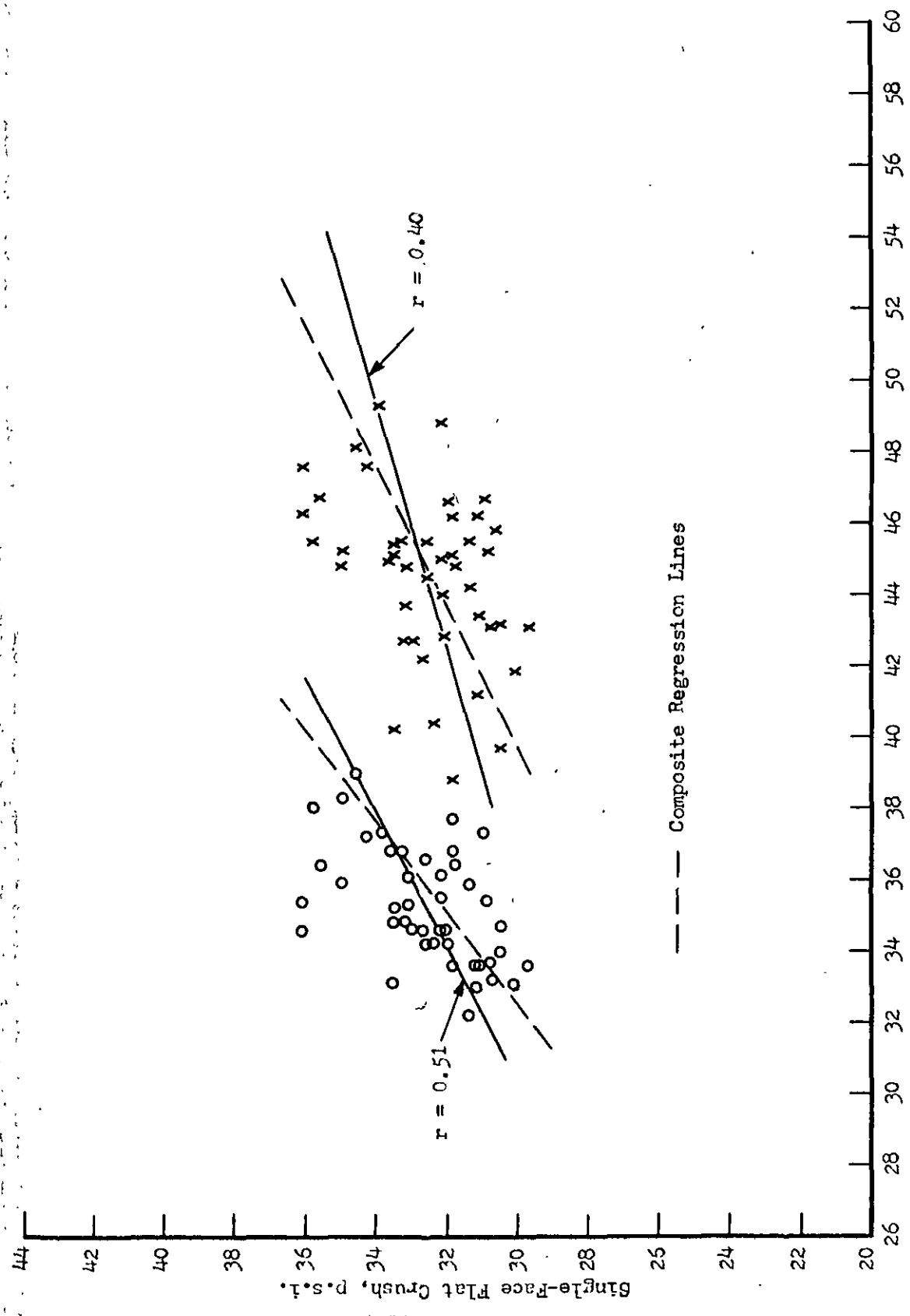

Figure 13. Single-Face Flat Crush versus Concora Flat Crush for Machine M

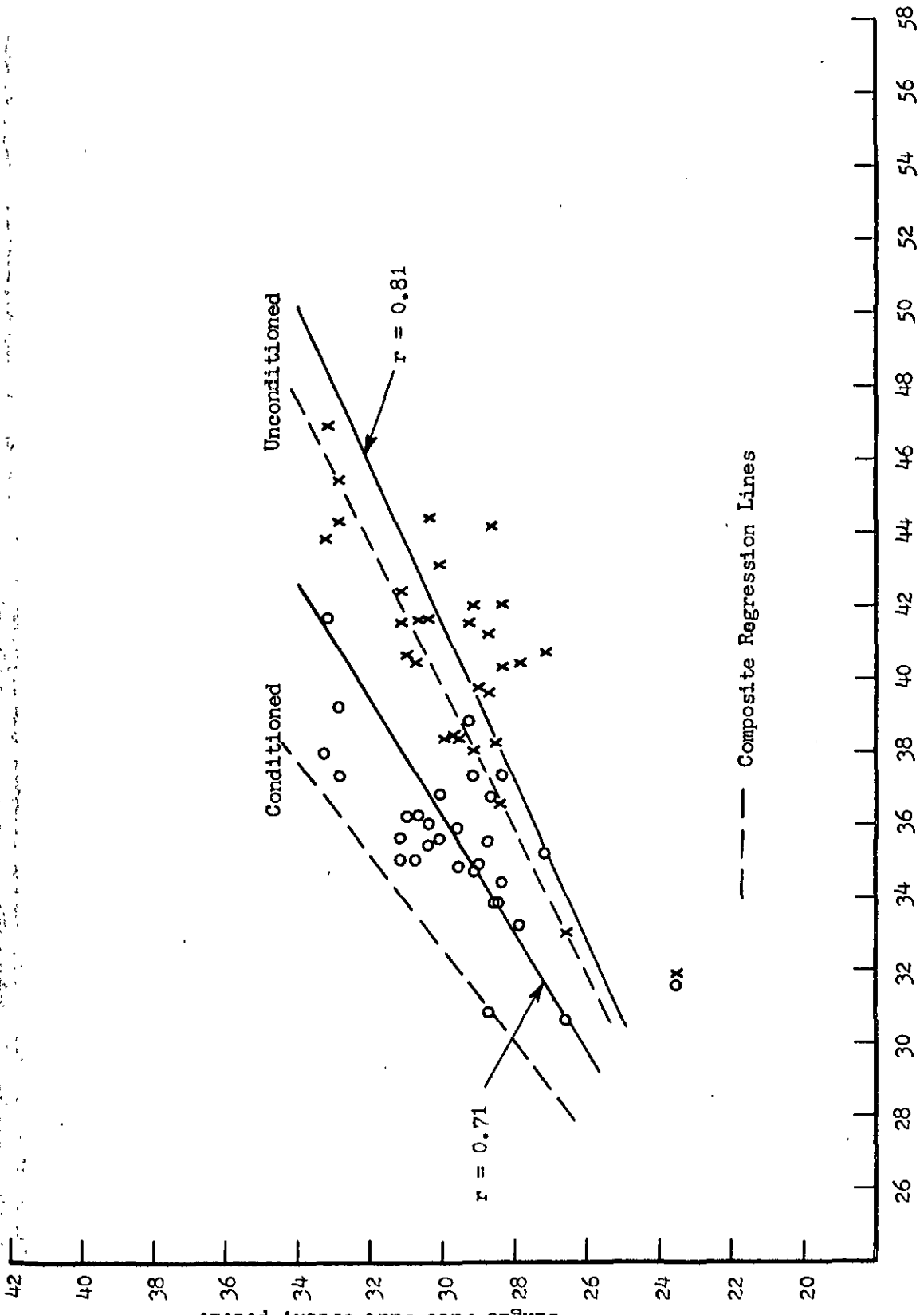

Figure 14. Single-Face Flat Crush versus Concora Flat Crush for Machine N

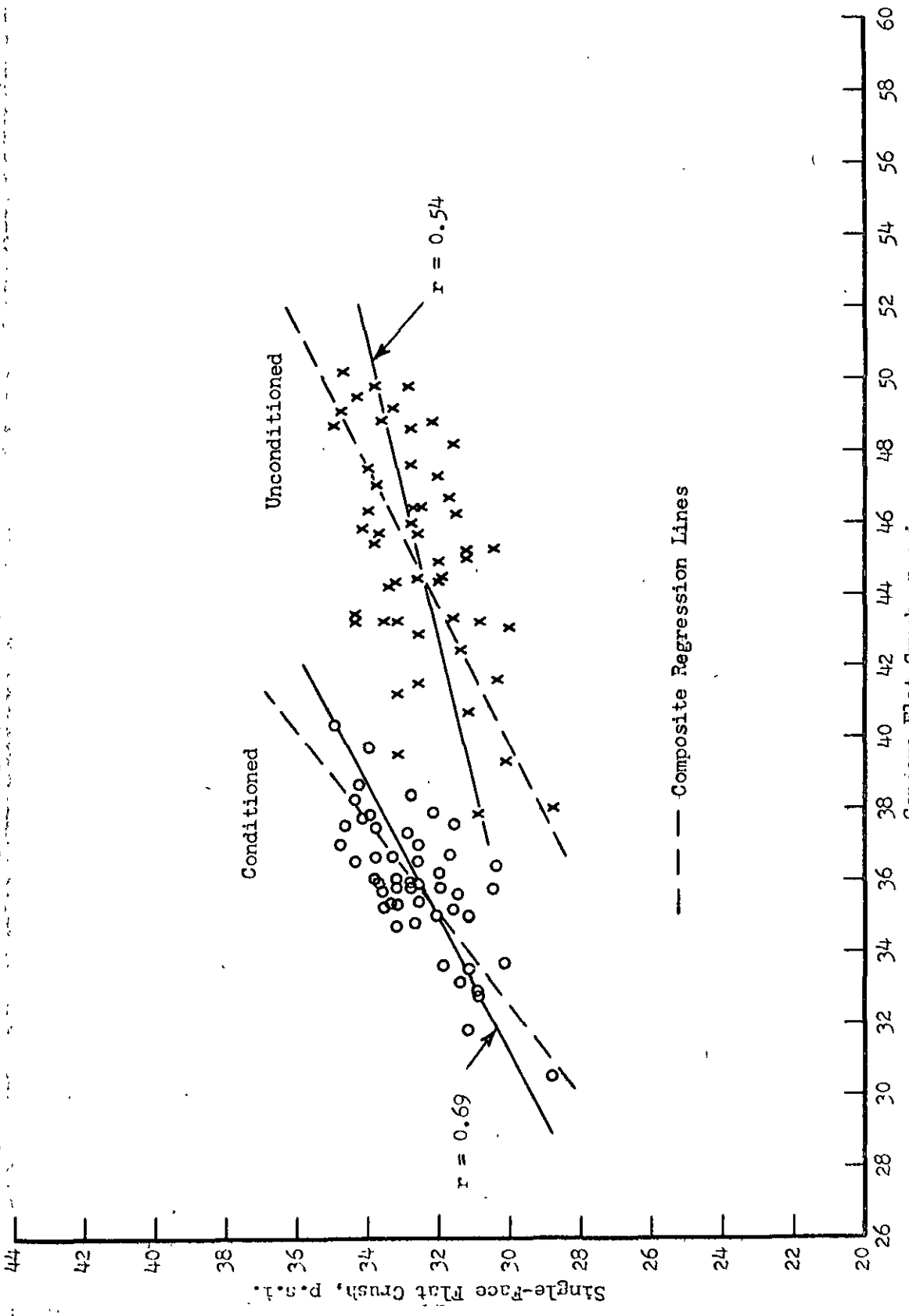

Figure 15. Single-Face Flat Crush versus Concora Flat Crush for Machine O

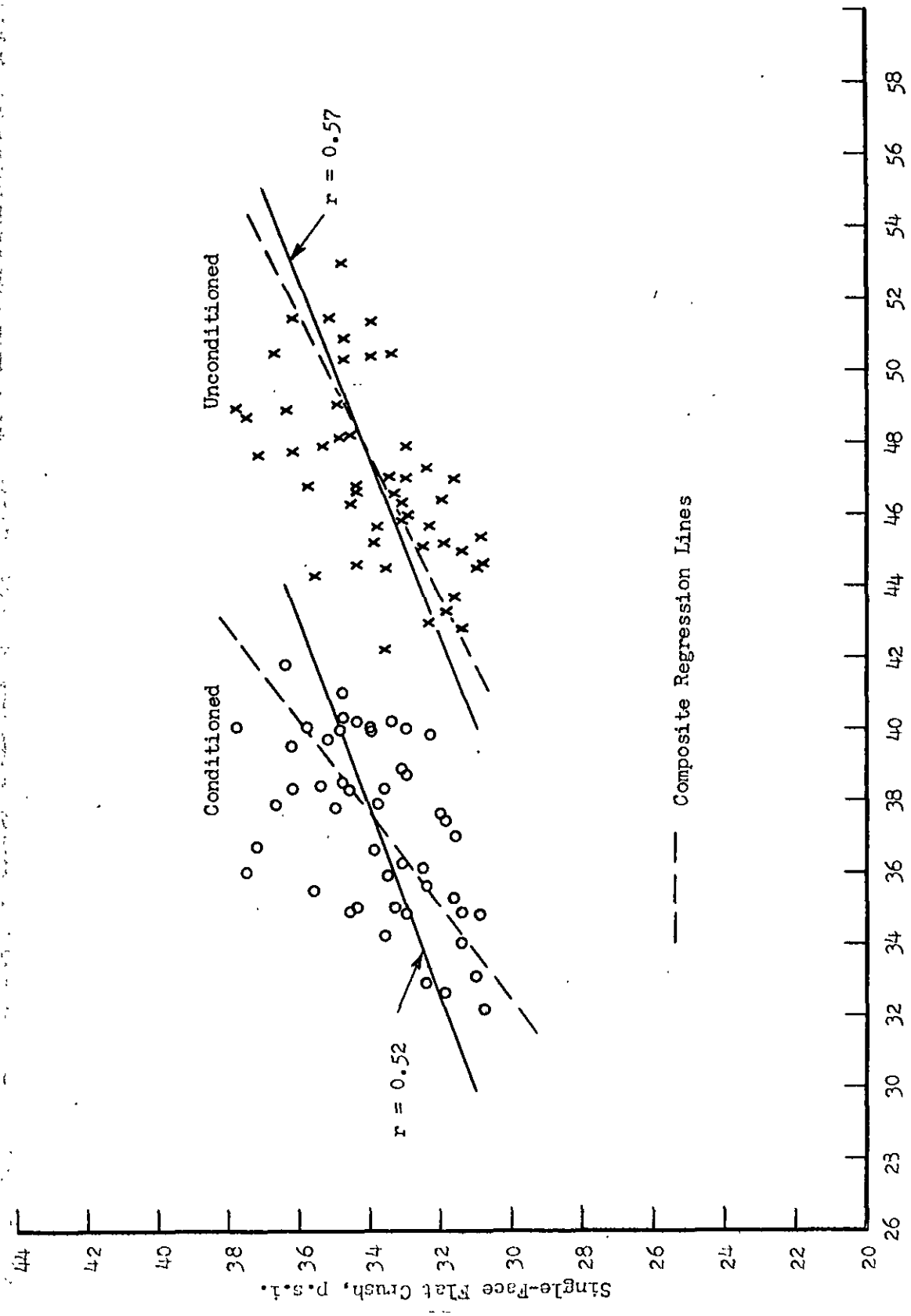

Figure 16. Single-Face Flat Crush versus Concora Flat Crush for Machine P

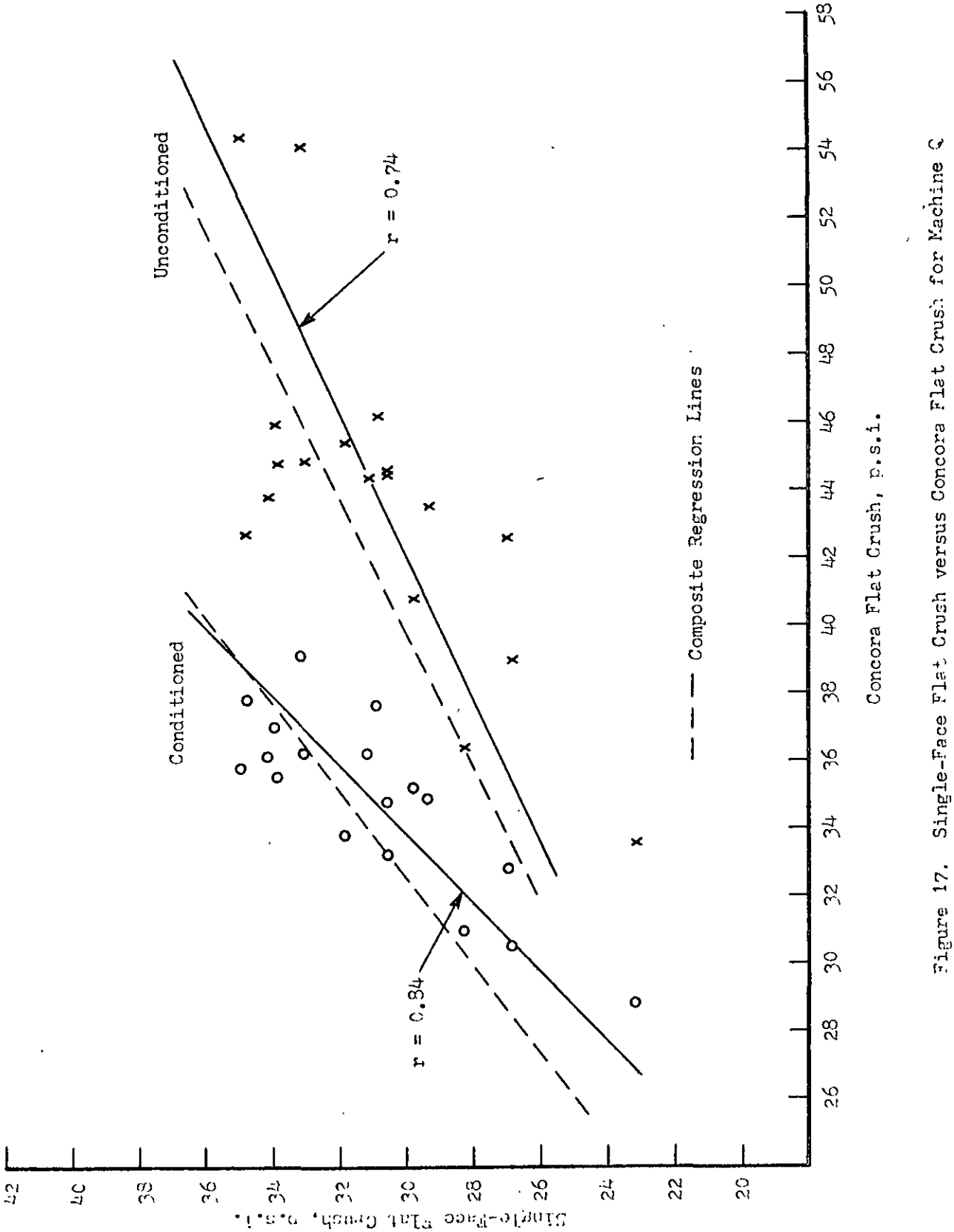

Figure 17. Single-Face Flat Crush versus Concora Flat Crush for Machine C

mill establish a relationship for its own materials and industry standards become more difficult to formulate.

In Fig. 18 are shown three possible cases for comparison of regression lines which might exist when an attempt is made to compare the individual machines regression equations with the composite equation for the combined data.

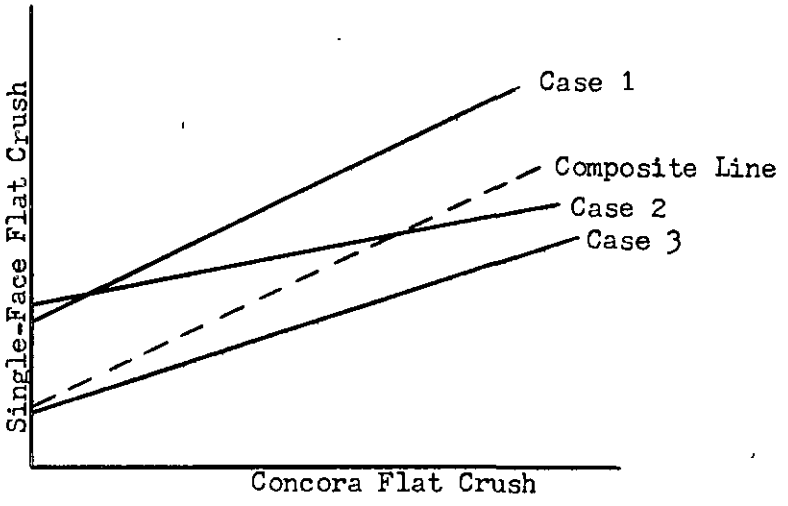

Figure 18. Comparison of Regression Lines

Case 1 would be where the slope of the two regression lines (Case 1 and composite line) are similar but are offset by such a distance that, for a given Concora flat-crush result, there would be a significant difference in the levels of single-face flat crush. Case 2, where it is clearly evident that there exists a significant difference in both the slope and intercepts of the two regression lines. Case 3 would be the opposite of the first case; although the intercepts are similar, it is the difference in slopes that result in a difference in the level of single-face flat crush obtained from any given Concora result.

The tests of significance which were performed on the comparisons of the slopes pertinent to Cases 2 and 3 for the relationship of single-face flat crush versus conditioned Concora flat crush are shown in Table III. Table III indicates that three machines, C, O, and P, have regression lines with slopes that are significantly different than the composite slope, thus making it undesirable for three machines or associating mills to use the composite regression equation for estimating single-face flat crush from their conditioned Concora results. It may be advantageous for the mills associated with the remaining machines to use the composite regression equation in place of the individual mills regression equation, because of vastly more data and the wider range of results used in estimating the regression coefficients would result in the best estimate of the true regression line.

The comparisons between the slopes of the individual machine's regression line and the composite regression line, which were statistically analyzed by tests of significance, are shown also in Table III for the relationship of single-face flat crush with unconditioned Concora flat crush. As indicated, there were four machines, namely, C, L, M, and O, with slopes significantly different than the composite slope.

The preceding discussion focussed attention upon the differences in slope among the regression lines. Similar tests were not performed for the Case 1 type of situation where the slopes would be similar but the intercepts different. However, reference to Fig. 1 through 17 indicates that the situation may be present for a number of the machines. Examples are Fig. 1 and 14 for Machines A and N, respectively, for the relation of single-face flat crush with Concora conditioned flat crush. Figures 7 and 17 would be similar examples

TABLE III

TEST OF SIGNIFICANCE OF THE DIFFERENCE IN SLOPES BETWEEN THE INDIVIDUAL MACHINES AND THE COMPOSITE REGRESSION LINES

	Relationship of Single-Face Flat Crush with A--Concora Conditioned Flat Crush				B--Concora Unconditioned Flat Crush			
Machine	Slope(b)	$b - b_o$	s_b	"t"	Slope(b)	$b - b_o$	s_b	"t"
A	0.405	-0.098	0.084	-1.17	0.787	0.015	0.117	0.13
B	0.530	0.027	0.063	0.43	0.888	0.116	0.083	1.40
C	0.183	-0.320	0.089	-3.60[a]	0.543	-0.229	0.091	-2.52[a]
D	0.438	-0.065	0.080	-0.81	0.724	-0.048	0.101	-0.48
E	0.411	-0.092	0.081	-1.14	0.672	-0.100	0.141	-0.71
F	0.448	-0.055	0.163	-0.34	0.738	-0.034	0.219	-0.16
G	0.316	-0.187	0.092	-2.03	0.407	-0.365	0.183	-1.99
H	0.587	0.084	0.060	1.40	0.893	0.121	0.071	1.70
I	0.573	0.070	0.059	1.19	0.719	-0.053	0.081	-0.65
J	0.611	0.108	0.070	1.54	0.709	-0.063	0.081	-0.78
K	0.401	-0.102	0.102	-1.00	0.709	-0.063	0.109	-0.58
L	0.213	-0.290	0.098	-2.96[a]	0.540	-0.232	0.128	-1.81
M	0.282	-0.221	0.099	-2.23[a]	0.524	-0.248	0.134	-1.85
N	0.462	-0.041	0.063	-0.65	0.623	-0.149	0.117	-1.27
O	0.240	-0.263	0.053	-4.96[a]	0.531	-0.241	0.079	-3.05[a]
P	0.398	-0.105	0.084	-1.25	0.380	-0.392	0.090	-4.36[a]
Q	0.470	-0.033	0.107	-0.31	0.982	0.210	0.162	1.30

Note: The tests of significance are of the form "t" = $\frac{b - b_o}{s_b}$ where:

b_o = the slope of the composite regression line which for relationship A is 0.503 and B is 0.772

s_b = the standard error associated with the slopes of the individual machines regression lines.

[a] Indicates significance at the 5% level.

for the relationship of single-face and unconditioned Concora flat crush.

To illustrate the use of the regression equations and to obtain an indication of the precision with which single-face flat crush may be predicted, the conditioned Concora results from two of the individual machines, namely, H and L, were substituted in their respective regression equations. (Note: The correlation coefficient for Machine H was 0.89 for 41 samples; the correlation coefficient for Machine L was 0.55 for 42 samples submitted.) The estimated or computed values obtained were compared to the observed single-face results and the per cent differences calculated based upon the observed results. In Table IV are presented the results of such comparisons for Machine H and, as may be noted, the difference range from a low of -13.1% to a high of +8.0%. Similarly, the results for Machine L are shown in Table V where the range of difference is -8.2% to +11.1%.

The unconditioned Concora results for Machines H and L also were used to estimate or predict single-face flat crush from their respective regression equations. These estimated or computed values are shown also in Tables IV and V (for Machines H and L, respectively) along with the observed results and the per cent differences based on the observed results. From Table IV, the per cent differences range from -10.7% to +10.9% while similarly from Table V, the range is -11.1% to +10.5%.

By way of summary for the predictability of single-face flat crush from Concora flat crush, the following is a distributior of the per cent differences between observed and computed single-face flat crush values shown as a percentage of the total number of samples submitted:

TABLE IV

COMPARISON OF THE OBSERVED TO THE ESTIMATED SINGLE-FACE FLAT CRUSH

USING BOTH CONCORA FLAT CRUSH RESULTS FOR MACHINE H

Reporting Period	Concora Conditioned Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i. Estimated	Single-Face Flat Crush, p.s.i. Observed	Difference, %[a]	Concora Unconditioned Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i. Estimated	Difference, %[a]
June, 1959	44.3	39.7	38.5	+3.1	52.4	37.4	-2.9
	41.3	37.0	34.7	+6.6	54.2	38.4	+10.7
	45.2	40.6	39.4	+3.0	50.8	36.4	-7.6
July, 1959	44.4	39.8	39.0	+2.1	55.0	38.8	-0.5
August, 1959	39.0	35.0	35.5	-1.4	46.3	33.8	-4.8
	41.6	37.4	38.2	-2.1	46.9	34.1	-10.7
	43.1	38.6	38.0	+1.6	55.2	39.0	+2.6
	46.7	41.9	40.3	+4.0	58.7	41.0	+1.7
	42.1	37.8	38.8	-2.6	52.8	37.6	-3.1
	47.4	42.5	39.6	+7.3	57.6	40.4	+2.0
September, 1959	40.1	36.0	37.6	-4.3	54.7	38.7	+2.9
	43.7	39.2	41.1	-4.6	58.9	41.2	+0.2
	40.0	35.9	38.1	-5.8	53.0	37.7	-1.0
	41.3	37.0	34.8	+6.3	54.6	38.6	+10.9
	43.9	39.4	41.7	-5.5	55.8	39.3	-5.8
	41.2	36.9	39.6	-6.8	53.8	38.1	-3.8
October, 1959	47.2	42.3	41.3	+2.4	62.0	43.0	+4.1
	36.2	32.5	30.1	+8.0	41.5	31.0	+3.0
	40.0	35.9	37.1	-3.2	49.2	35.5	-4.3
	37.9	34.0	34.6	-1.7	51.5	36.8	+6.4
	35.2	31.6	31.8	-0.6	44.6	32.8	+3.1
	37.8	33.9	33.1	+2.4	46.7	34.0	+2.7
November, 1959	37.9	34.0	36.0	-5.6	46.8	34.1	-5.3
	39.1	35.1	38.0	-7.6	51.4	36.7	-3.4
	36.5	32.8	34.5	-4.9	46.8	34.1	-1.2
	44.0	39.5	41.9	-5.7	53.0	37.7	-10.0
	36.6	32.9	31.0	+6.1	44.2	32.5	+4.8
	42.7	38.3	39.6	-3.3	51.4	36.7	-7.3
	37.7	33.8	34.2	-1.2	45.8	33.5	-2.0
December, 1959	40.6	36.4	36.7	-0.8	50.0	36.0	-1.9
	34.1	30.6	30.7	-0.3	43.8	32.3	+5.2
	37.4	33.6	31.5	+6.7	46.4	33.8	+7.3
	34.9	31.4	30.8	+1.9	46.7	34.0	+10.4
	37.9	34.0	34.3	-0.9	47.3	34.3	0.0
	42.5	38.1	37.4	+1.9	53.6	38.1	+1.9
	40.1	36.0	35.6	+1.1	51.6	36.9	+3.7
	38.3	34.4	33.6	+2.4	44.9	32.9	-2.1
	37.3	33.5	31.5	+6.3	44.6	32.8	+4.1
	38.6	31.1	35.8	-13.1	48.5	35.0	-2.2
	34.9	31.4	30.6	+2.6	40.6	30.4	-0.7
	35.9	32.2	30.1	+7.0	43.7	32.2	+7.0

[a] Based on observed values as reference.

TABLE V

COMPARISON OF THE OBSERVED TO THE ESTIMATED SINGLE-FACE FLAT CRUSH

USING BOTH CONCORA FLAT CRUSH RESULTS FOR MACHINE L

Reporting Period	Concora Conditioned Flat Crush p.s.i.	Single-Face Flat Crush, p.s.i. Estimated	Single-Face Flat Crush, p.s.i. Observed	Difference, %[a]	Concora Unconditioned Flat Crush, p.s.i.	Single-Face Flat Crush, p.s.i. Estimated	Difference, %[a]
June, 1959	38.9	34.9	34.8	+0.3	45.7	33.6	-3.4
	37.2	34.0	32.0	+6.2	43.6	33.1	+3.4
	37.4	34.1	33.0	+3.3	46.9	33.8	+2.4
	36.7	33.7	34.2	-1.5	44.3	33.3	-2.6
	37.1	33.9	30.5	+11.1	46.1	33.7	+10.5
	37.3	34.1	33.6	+1.5	43.6	33.1	-1.5
	35.8	33.2	30.5	+8.9	41.9	32.8	+7.5
July, 1959	34.1	32.3	31.1	+3.9	41.8	32.8	+5.5
	39.5	35.2	35.8	-1.7	47.5	34.0	-5.0
	36.5	33.6	36.6	-8.2	41.6	32.7	-10.7
	34.7	32.6	34.6	-5.8	45.1	33.5	-3.2
	35.3	33.0	32.3	+2.2	41.3	32.6	+0.9
	39.7	35.4	35.2	+0.6	48.1	34.1	-3.1
August, 1959	37.2	34.0	35.7	-4.8	48.2	34.1	-4.5
	37.2	34.0	35.0	-2.9	40.4	32.5	-7.1
	37.4	34.1	37.0	-7.8	42.6	32.9	-11.1
September, 1959	36.4	33.6	30.7	+9.4	44.6	33.4	+8.8
	36.6	33.7	35.3	-4.5	43.9	33.2	-5.9
	37.4	34.1	34.2	-0.3	43.9	33.2	-2.9
	33.8	32.2	31.1	+3.5	43.2	33.0	+6.1
	35.9	33.3	33.9	-1.8	45.8	33.6	-0.9
October, 1959	36.7	33.7	35.8	-5.9	47.9	34.0	-5.0
	33.5	32.0	30.4	+5.3	43.3	33.1	+8.9
	34.8	32.7	32.2	+1.6	41.4	32.7	+1.6
	34.9	32.8	34.3	-4.4	40.0	32.4	-5.5
	34.7	32.6	34.8	-6.3	44.6	33.4	-4.0
	36.7	33.7	33.3	+1.2	48.6	34.2	+2.7
	36.7	33.7	31.2	+8.0	43.2	33.0	+5.8
	34.8	32.7	31.8	+2.8	42.7	33.0	+3.8
November, 1959	35.0	32.8	33.0	-0.6	45.7	33.6	+1.8
	33.0	31.7	32.9	-3.6	49.1	34.3	+4.3
	35.0	32.8	32.4	+1.2	47.0	33.9	+4.6
	35.4	33.0	34.2	-3.5	45.0	33.4	-2.3
	34.8	32.7	33.9	-3.5	45.2	33.5	-1.2
	32.9	31.7	32.3	-1.9	39.4	32.2	-0.3
December, 1959	35.9	33.3	33.7	-1.2	43.9	33.2	-1.5
	31.0	30.6	30.5	+0.3	38.2	32.0	+4.9
	35.8	33.2	32.3	+2.8	46.6	33.8	+4.6
	37.6	34.2	34.9	-2.0	45.1	33.5	-4.0
	34.6	32.6	32.5	+0.3	44.3	33.3	+2.5
	33.1	31.8	30.6	+3.9	39.6	32.3	+5.6
	39.2	35.1	34.1	+2.9	49.3	34.4	+0.9

[a] Based on observed values as reference.

Machine	Concora Test Conditioned	No. of Samples	Distribution, % ±2%	±4%	±6%	±8%	±10%
H	Conditioned	41	26.8	53.7	73.2	95.1	97.6
H	Unconditioned	41	22.0	56.1	75.6	87.8	87.8
L	Conditioned	42	35.7	66.7	81.0	88.1	97.6
L	Unconditioned	42	21.4	47.6	81.0	88.1	92.9

It may be observed that when unconditioned Concora flat-crush results are used to estimate the single-face flat-crush values, the percentage in each range is less than when the conditioned results are used, thus indicating that a slightly better estimate of single-face flat crush is obtained using the conditioned Concora results.

RELATIONSHIP BETWEEN CONDITIONED AND UNCONDITIONED CONCORA FLAT CRUSH

The degree of relationship between the two Concora flat-crush results, conditioned and unconditioned, as determined by composite intercorrelation coefficients obtained from all the data combined is 0.81. As may be seen in Table VI, for the individual machines the degree of relationship between the two Concora results on the basis of individual machine are also shown in Table VI. The intercorrelation coefficients which measure the degree of relationship range from a high of 0.87 for Machine H to the low of 0.46 for Machine C.

In testing, if a real relationship exists between these two variables for the individual machines, the intercorrelation coefficients must be significantly greater than zero. To determine if this condition

TABLE VI

RELATIONSHIP OF CONDITIONED TO UNCONDITIONED

CONCORA FLAT CRUSH AND SIGNIFICANCE VALUES

Machine	No. of Samples	Intercorrelation Coefficients	Tabulated Values of Significance
A	54	0.76	0.27
B	53	0.76	0.27
C	56	0.46	0.26
D	56	0.76	0.26
E	20	0.81	0.44
F	20	0.58	0.44
G	22	0.61	0.42
H	41	0.87	0.31
I	57	0.86	0.26
J	48	0.74	0.28
K	46	0.66	0.29
L	42	0.53	0.30
M	44	0.52	0.30
N	30	0.85	0.36
O	51	0.65	0.28
P	49	0.65	0.28
Q	18	0.76	0.47
Composite	707	0.81	

Note: Tabulated values of significance at the 5% level.

exists the intercorrelation coefficients have to be greater than a tabulated value obtained from tables of significance for correlation coefficients. These tabulated values are shown also in Table VI and are based on N-2 degrees of freedom. It may be noted from Table VI that, for every machine, a real relationship exists between the conditioned and unconditioned Concora flat-crush results.

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